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WHEY CONCENTRATION by REVERSE OSMOSIS

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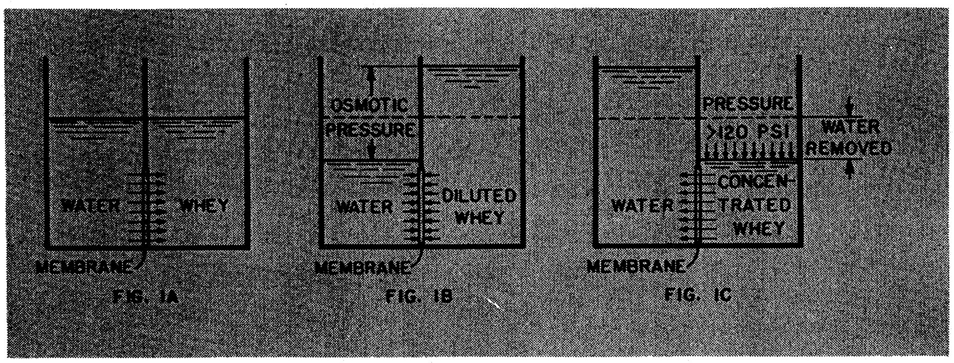
WHEY CONCENTRATION by REVERSE

Principle of reverse osmosis offers small plants a lower-cost method of partially removing water from a product like whey. Further development under way to refine the process



FIGS. 1A and 1B show osmosis where flow proceeds from less concentrated side through membrane to more concentrated side. **FIG. 1C** shows reverse osmosis wherein pressure is exerted on concentrated side to reverse the flow.

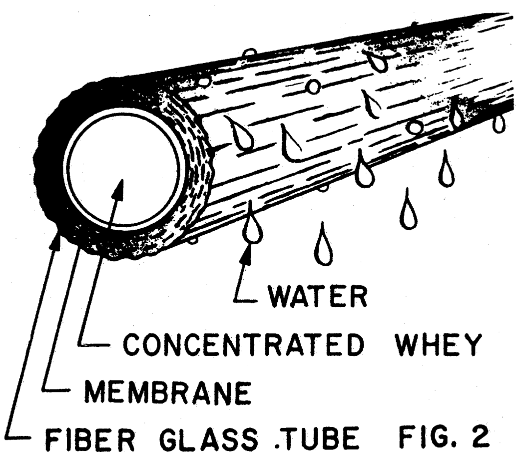
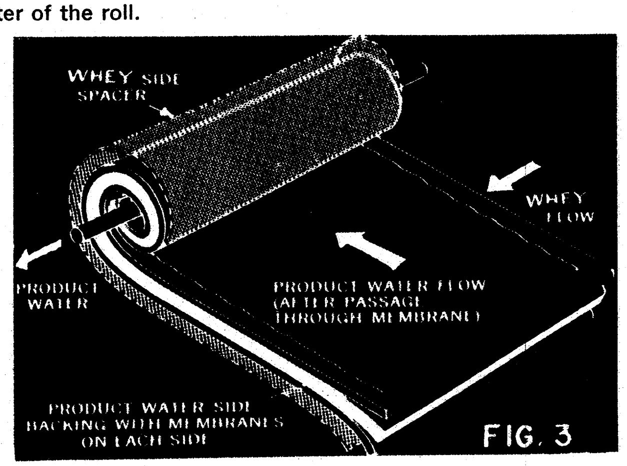


FIG. 2

TUBULAR concept employs a hollow support tube that is lined with a membrane. Feed liquid circulates through tubes at desired pressure, product water passes through and is collected from outside surfaces of tubes.

SPIRAL-WOUND MODULE has membrane folded over a porous fiber glass backing with product-water take-off tube at the center of the roll.



DISPOSAL of cheese whey has become a critical problem. Factories that dump whey into streams are now being required to find other methods of disposal, pay sewer-use premiums, or discontinue manufacture. About 22 billion lb of whey, containing half the solids of milk and rich in vitamins, amino acids, lactose, and soluble proteins, are produced annually in the U.S.

Whey is highly perishable and usually must be concentrated and/or dried for food use. It contains 93.5% water, and concentrating and drying by existing methods is too expensive for small volume plants. Reverse osmosis appears to promise a relatively cheap method of removing at least part of the water from whey. Small plants, not able to afford conventional equipment, may be able to concentrate whey with cheaper reverse osmosis units and then ship the whey to central plants for drying.

Whey Concentration

Cheddar cheese whey has been concentrated experimentally by

OSMOSIS

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TABLE I. Composition of Whey Concentrated by Reverse Osmosis

Composition	Initial Whey	Concentrated Whey
Total solids %	6.3	23.0
pH at 25C	5.4	5.7
Lactose %	4.79	18.65
Titratable acidity %	1.10	3.34
Total nitrogen %	.14	.49

TABLE II. Rate and Composition of Water Removed From Whey by Reverse Osmosis*

Membrane No.	1	2	3
Membrane—Desalting ratio	2.5:1	10:1	20:1
Membrane area (ft²)	55	55	55
Feed pressure (psi)	650	650	650
Flux rate (gal/ft²/day)			
Stage 1**	11.90	7.70	5.40
Stage 2	7.07	6.26	5.44
Stage 3	5.44	5.17	5.17
Stage 4	4.35	3.81	3.67
Average	7.19	5.58	4.90
Analyses			
Filtrate			
Total solids %	.343	.044	.034
Total nitrogen %	.0152	.0088	.0066
Lactose %	NIL	NIL	NIL
Titratable acidity %	.255	.135	.095
Dissolved solids (ppm)***			
Stage 1**	400	135	85
Stage 2	1150	220	130
Stage 3	1500	290	170
Stage 4	2000	380	215

*Using Havens "Osmotik" unit with three different membranes.

**Flux rates determined and filtrate samples taken during stages of concentration referring to:

	Total solids %
Stage 1	6.3- 9.5
Stage 2	9.5-13.2
Stage 3	13.2-15.7
Stage 4	15.7-23.0

***As determined by Myron L Delux D S Meter (Conductivity Type)

a number of organizations using the reverse osmosis principle. Tables I and II present typical results obtained in the Dairy Products Laboratory using membranes of three different porosities with salt rejection ratios of 2.5:1, 10:1, and 20:1. As expected, the flux rates (water removal rates) decreased with concentration due to corresponding increase in osmotic pressure. In these tests, the flow through the looser membranes decreased at a slightly greater rate than the flow through the tight membrane. Nevertheless, the composite flux rates of the looser membrane remained significantly greater.

The titratable acidity, total solids, nitrogen, and lactose contents of the filtrates indicate that practically no high molecular weight material was lost. Ionizable salts and lactic acid passed through. That most likely is desirable since the amount of whey which can be added to food products is often limited because of its salty nature. In addition, with the proper choice of membranes, there is the possibility of demineralizing and/or fractionating whey.

Flux data shown give some indication of processing output capabilities. The average flux rates while removing 75% of the water were 7.19, 5.58, and 4.90 gfd (gallons/ft²/day) for the loose, intermediate, and tight membranes. Thus, a cheese plant processing 150,000 lb of milk/day would require from 2200-3200 sq ft of membrane surface to treat its whey. Space requirements for such a unit would vary from 10 cu ft to 20 cu ft, depending upon the module design. These figures represent a maximum requirement. Higher pressures are known to result in higher flux rates. Aerojet-General has concentrated whey to a whipping cream consistency of 56% solids using loose membranes and 1500 psi at an average flux rate of 11.5 gfd. Termination of the run at 41% solids would have given an average flux of 19.4 gfd or about three times the rate reported here at 650 psi.

However, there are problems with the use of high pressure, e.g., pressures in excess of 850 psi may cause compaction and short life of the membrane.

Outlook for Reverse Osmosis

The economics of reverse osmosis concentration of whey cannot be calculated accurately until answers to several questions are known. The only energy requirement is the electricity to operate the pump. No phase changes are necessary. Energy and operation costs should be extremely low. Initial capital outlay for equipment should be relatively low. Predominant factors affecting costs will be the life of the membranes and the processing or flux rates. Optimum processing conditions must be determined for each product: pressures, temperatures, pH, and feed rate. Most of the knowledge of reverse osmosis comes from work with saline water. Concentration of whey presents many different problems, one of which may be clogging of membranes with precipitated lactose. Whey is an excellent media for growth of bacteria, and methods of sanitation will be important.

Present tests indicate a membrane life of several months to several years. Perfection of the process and further development of membrane technology should result in additional improvement. Laboratory tests have been good and indicate that concentration of whey by reverse osmosis will be economically feasible. Longer-term experiments in pilot-plant equipment are now under way in the Dairy Products Laboratory to define the potentialities of the process.

Principle of Reverse Osmosis

There is nothing new about osmosis. Food and liquids used by the human body enter the bloodstream by osmosis. Plants absorb food and moisture from soil by osmosis. The basic principle is simple. When fluids of different concentrations are separated by a membrane (Fig. 1a), the dilute solution will flow through the membrane into the more concentrated solution until an equilibrium is reached (Fig. 1b).

The difference in pressure between these two levels is the **osmotic pressure.** If a pressure in excess of the osmotic pressure is applied to the concentrated side, the water from the whey will flow in the opposite direction. That is reverse osmosis (Fig. 1c).

In 1953, the Office of Saline Water, U.S. Dept. of the Interior, initiated a program at the University of Florida to study the feasibility of obtaining potable water from sea water by reverse osmosis. Since then, contributions by several scientists have led to success and an understanding of most of the practical problems. Researchers, including those at the U.S. Dept. of Agriculture, foresaw that removing water from a liquid product could have application in concentration.

In practice, reverse osmosis is accomplished by a semi-permeable cellulose-acetate membrane, about ⅓ micron (.000013 inches) in thickness, backed by a porous support material which allows passage of the product water. The product flows across the surface of the membrane while the water goes through.

Several types of support structures are now in use. The original type consisted of a membrane stack. Aerojet-General utilizes this type where disc-shaped membranes are bonded to support plates and the stacks of membranes and plates are separated into modules. The modules are separated by divider plates and are assembled onto a center shaft which collects the product water and feeds it to the outlet line.

Another method exemplified by Havens Osmotik and Universal Water Corp. employs the tubular concept (Fig. 2). A hollow support tube is lined with a continuous membrane and the feed liquid is circulated through the tubes at the desired pressure. The product water passes through and is collected from the outside surfaces of the tubes. Chief advantage of this design is the large amount of space in the tubes which allows the passage of large particles such as would be encountered in concentration of soups. Material may be pumped through with a high degree of turbulence, resulting in a scrubbing action and lessening the probability of clogging. In addition, deposits may be cleaned from the membrane surface with polyurethane plugs.

A third type of unit is the "spiral-wound module" of General Dynamics Corp. (Fig. 3). Membrane is folded over a porous fiberglass backing with a product water takeoff tube at the center of the roll. Chief advantage of this design is the increased amount of membrane surface that can be accommodated in a given volume. Tentative plans call for modules containing 200 sq ft to 300 sq ft of membrane per cubic foot of space. Although some concerns are working on other type membrane materials, cellulose acetate is presently the standard, and major competitive differences are the design and means of support for the membrane.

Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.